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# United States Patent [19]

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**Kveen et al.**

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[54] **HELICAL STENT DESIGN**

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[22] Filed: **Oct. 23, 1998**

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[51] **Int. Cl.**<sup>7</sup> ..... **A61M 29/00**

[52] **U.S. Cl.** ..... **606/198; 623/1**

[58] **Field of Search** ..... 606/198, 194, 606/191; 623/1, 12

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*Primary Examiner*—Michael Buiz

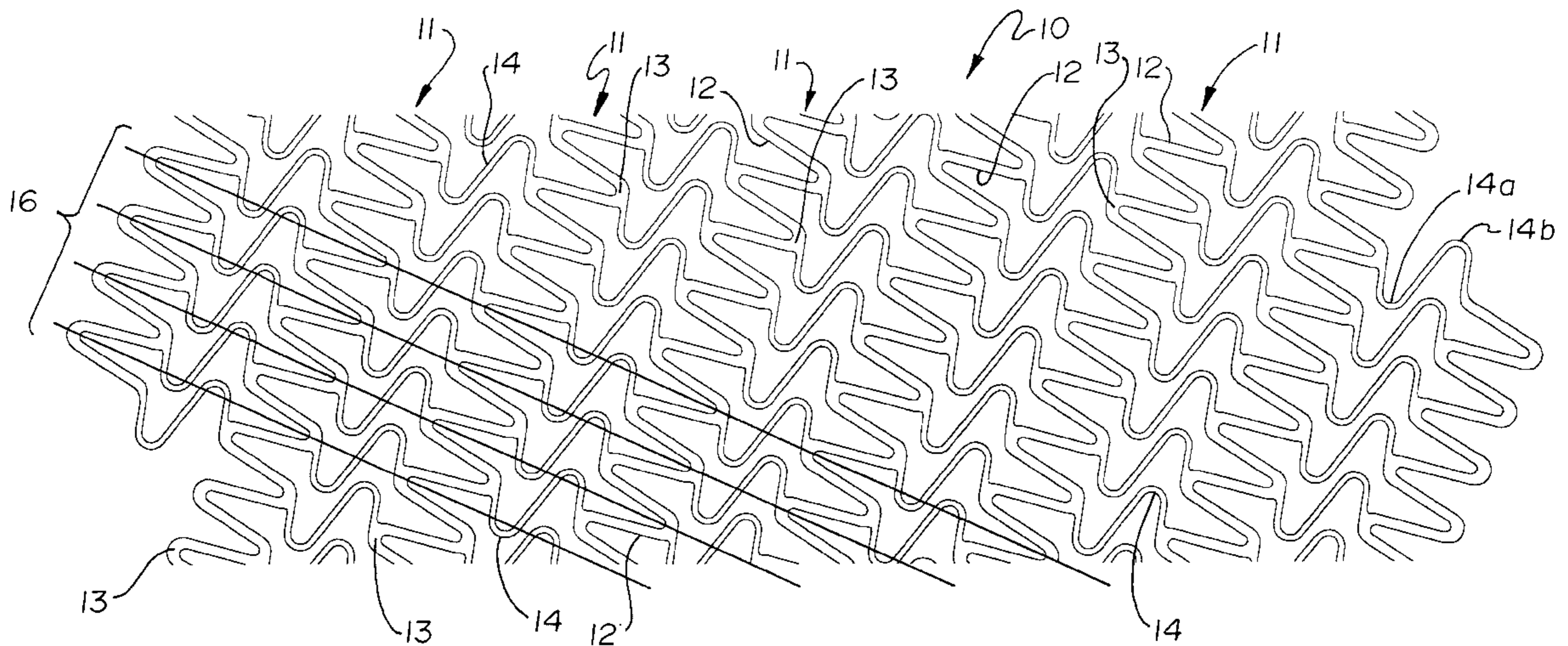
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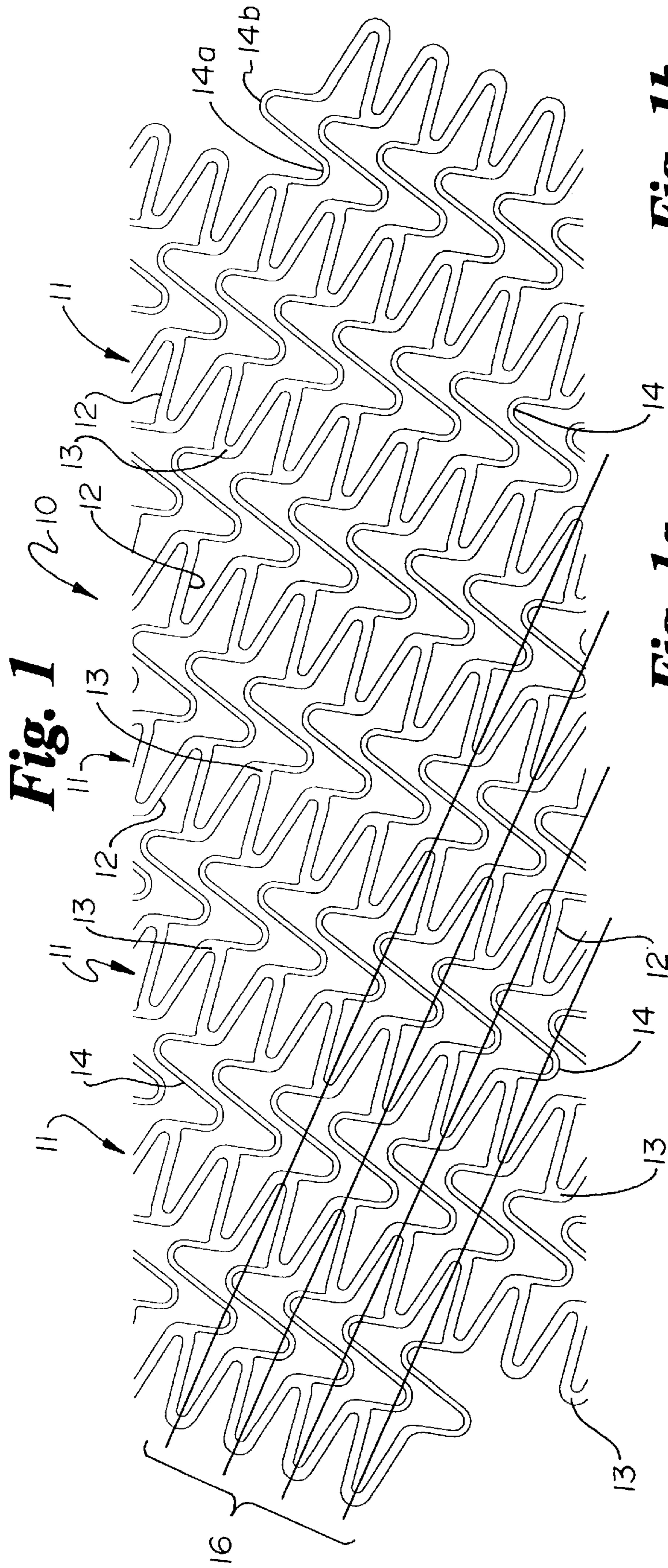
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### [57] ABSTRACT

An expandable tubular reinforcing member used for body lumens such as blood vessels, the reinforcing member being formed of a continuous elongated helical element comprised of spaced undulating portions forming end loop portions and including a plurality of curvilinear connector elements extending between and interconnecting at least some of the adjacent undulating portions of the helical element over its length.

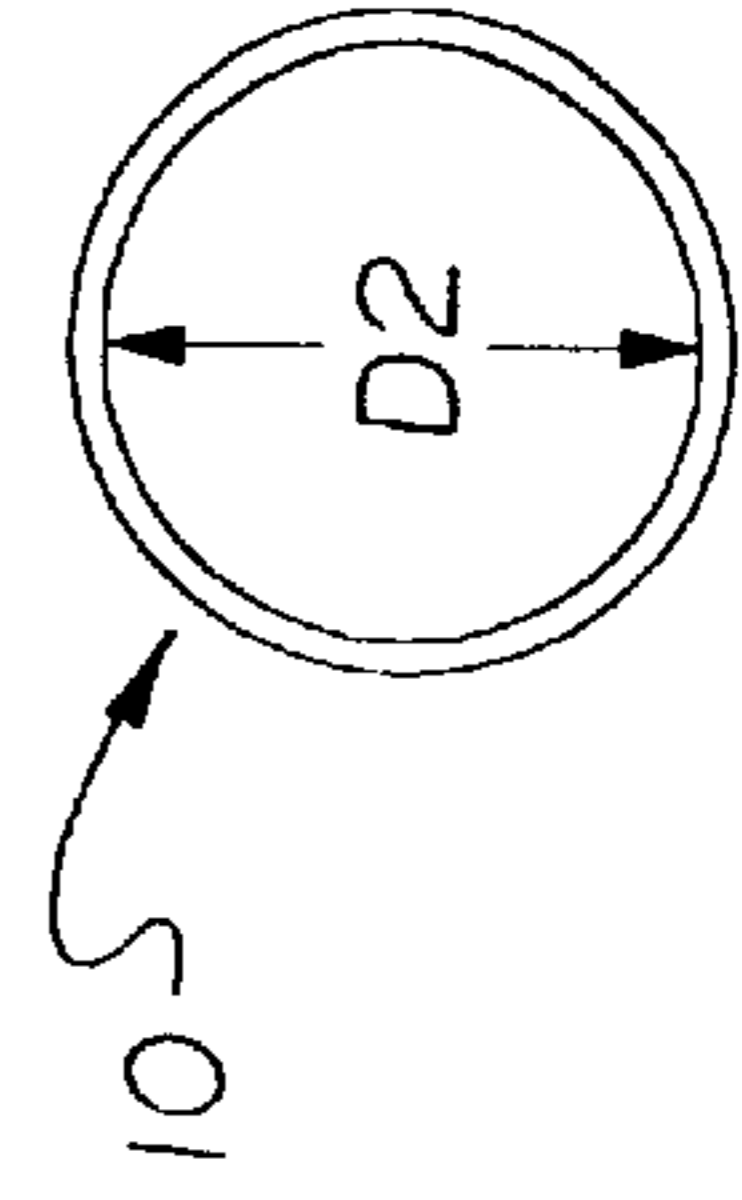
**23 Claims, 8 Drawing Sheets**



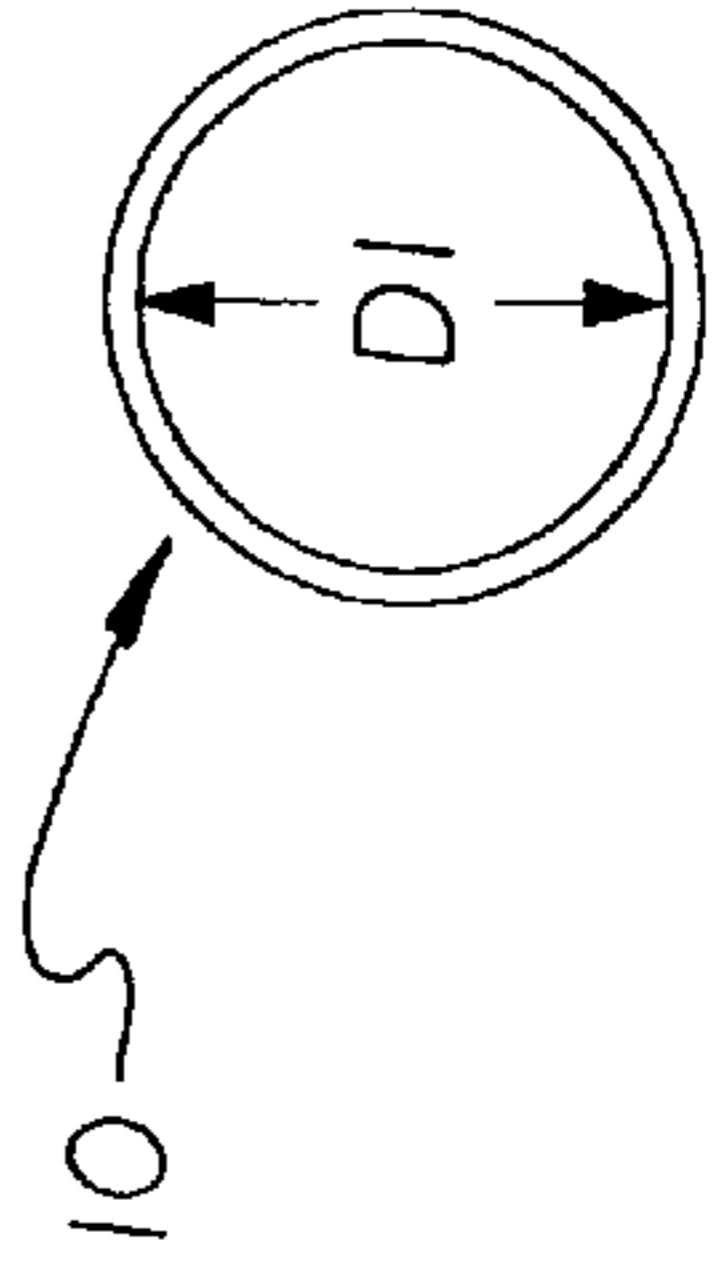


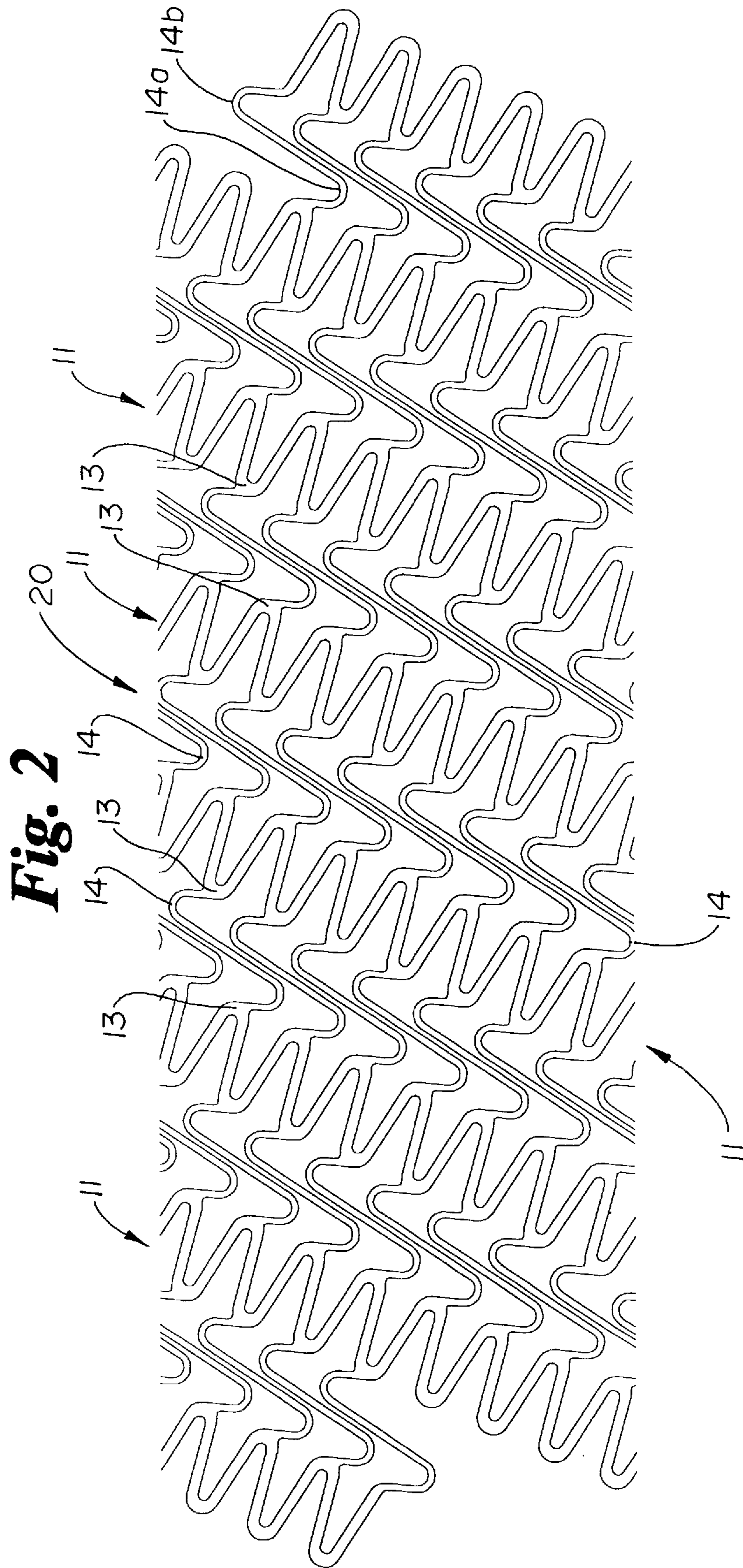
**Fig. 1**

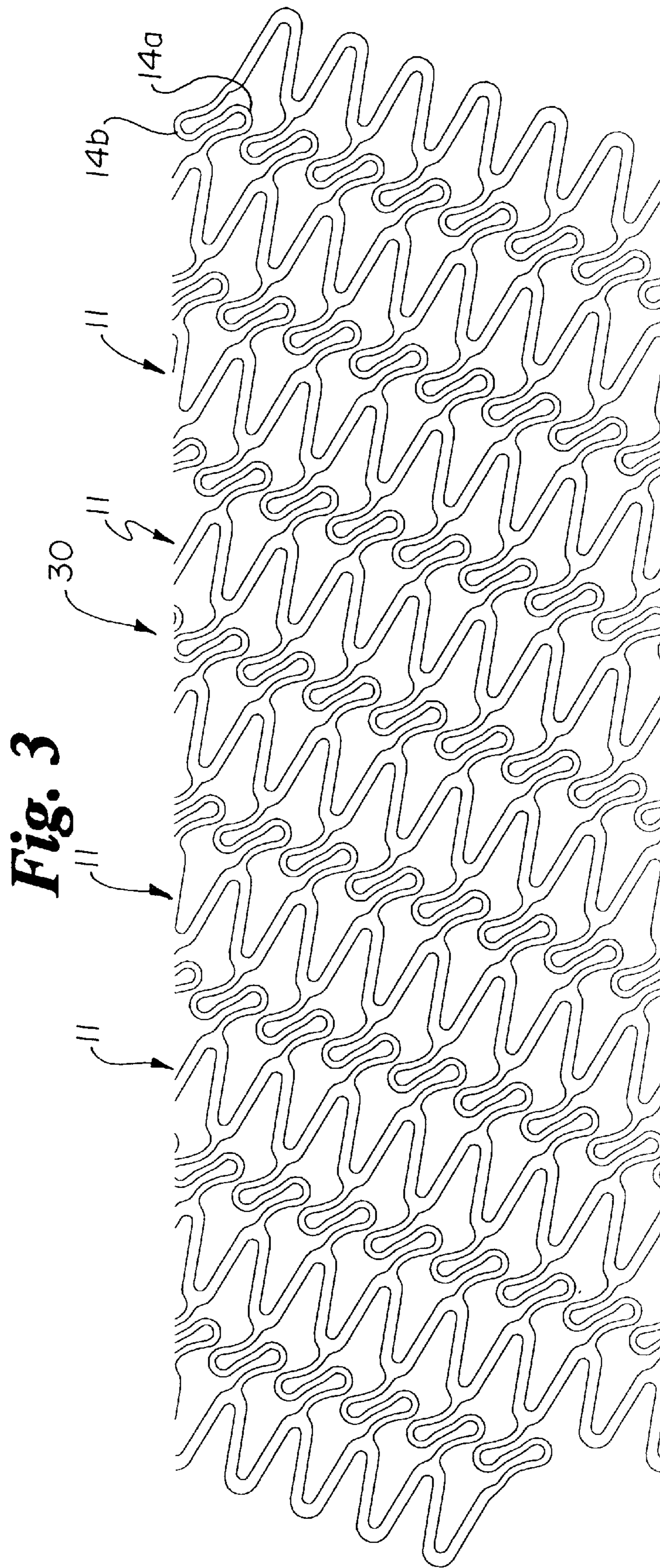
**Fig. 1b**

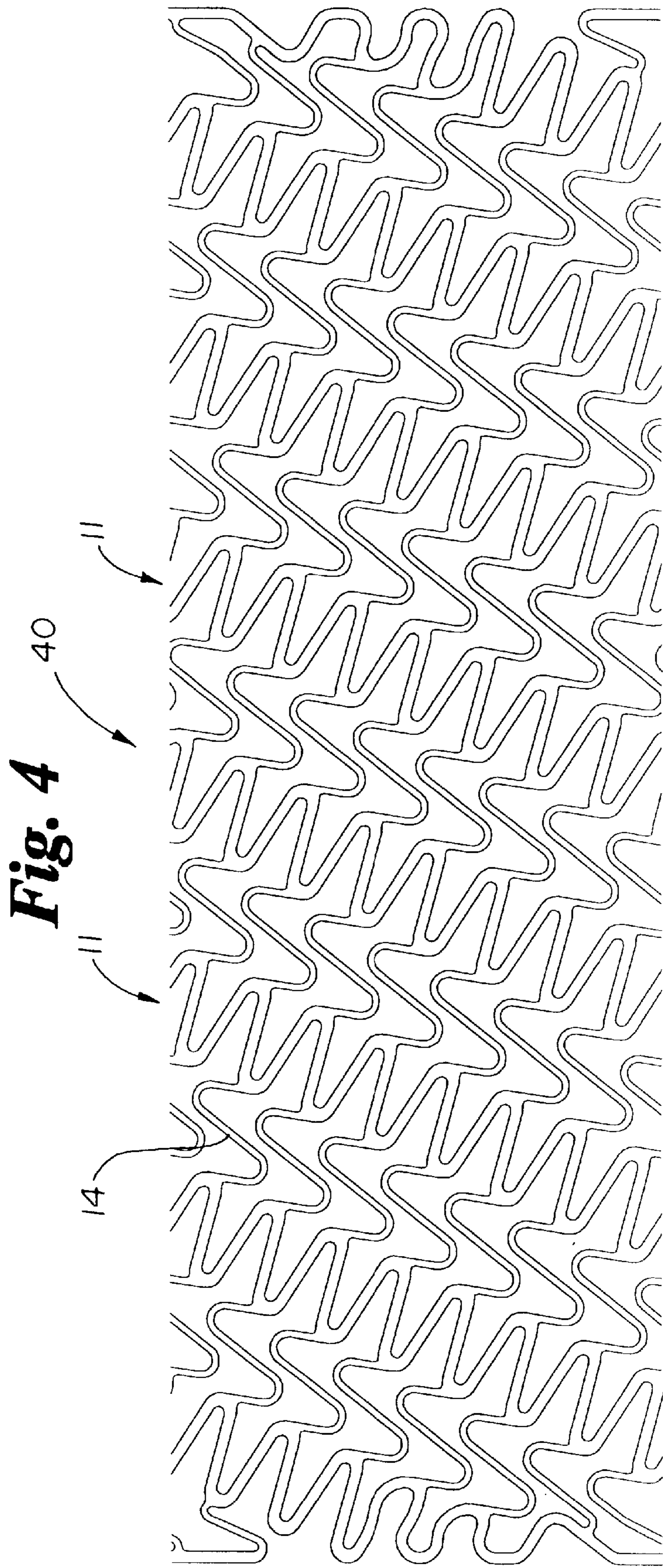


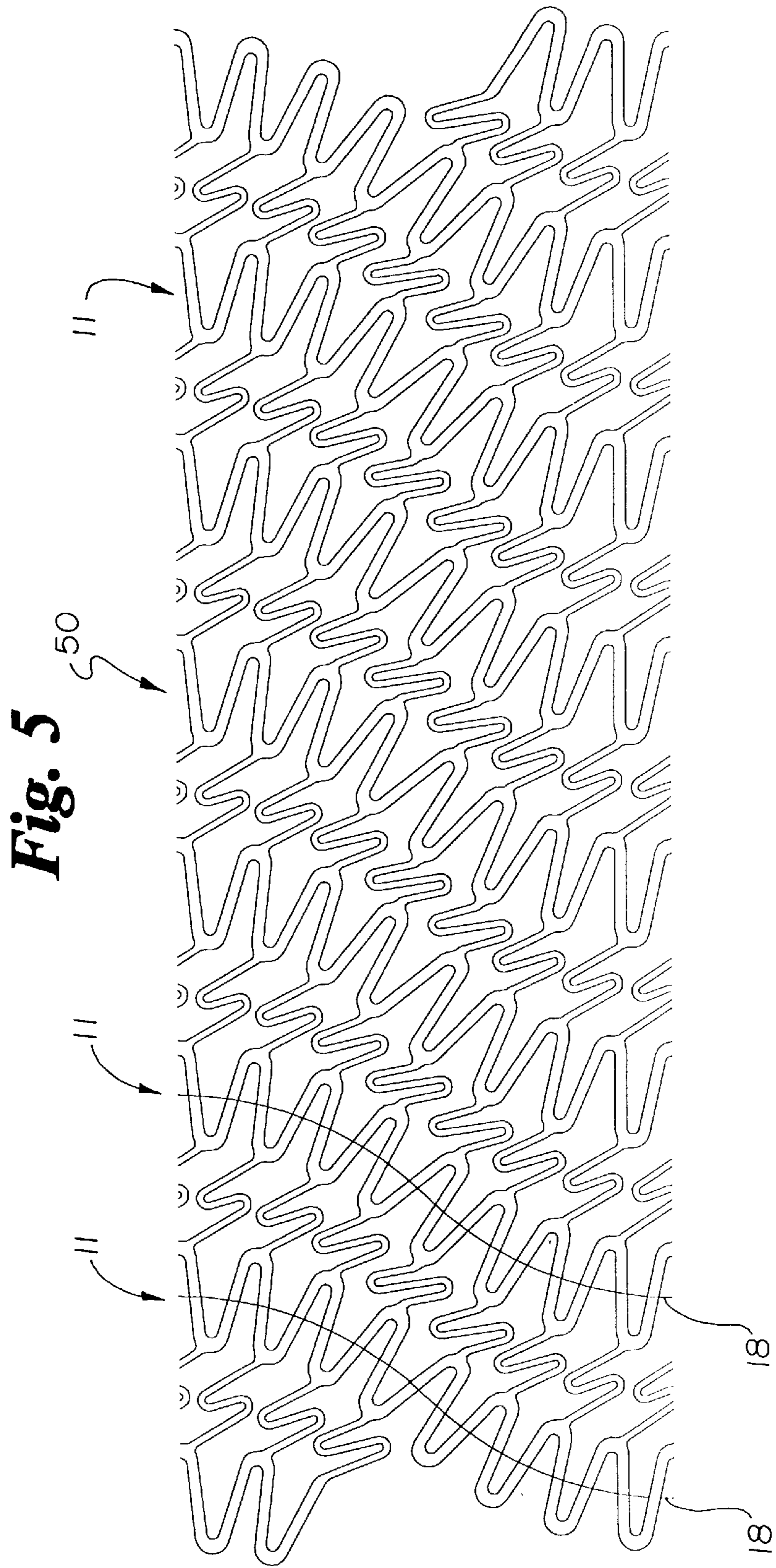
**Fig. 1a**



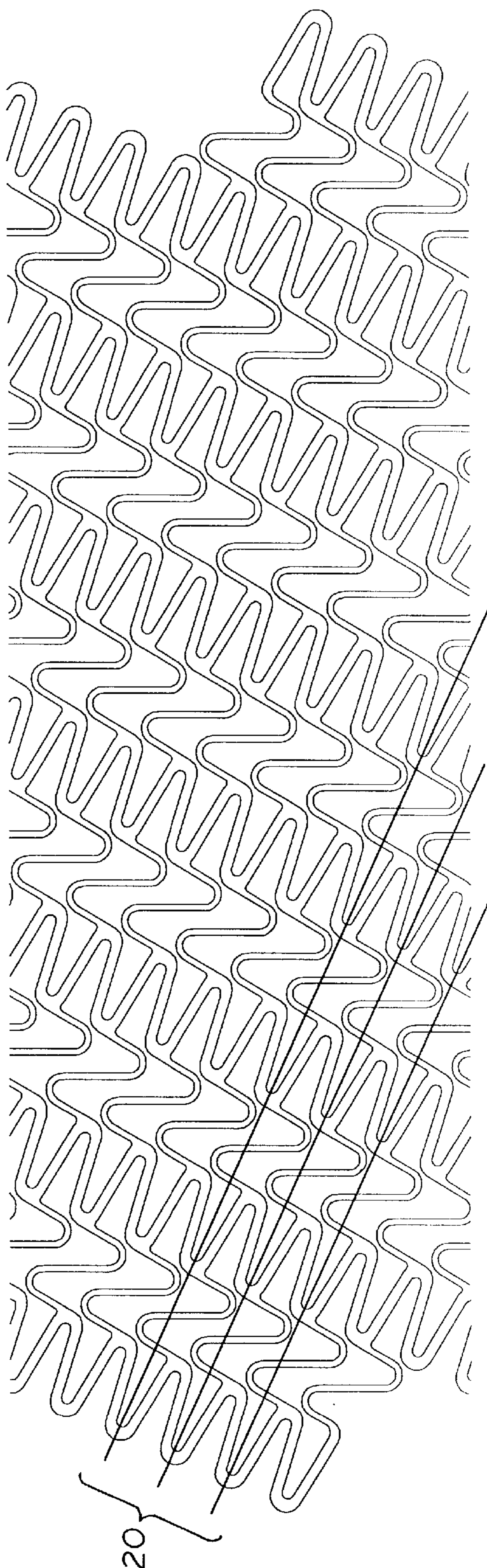




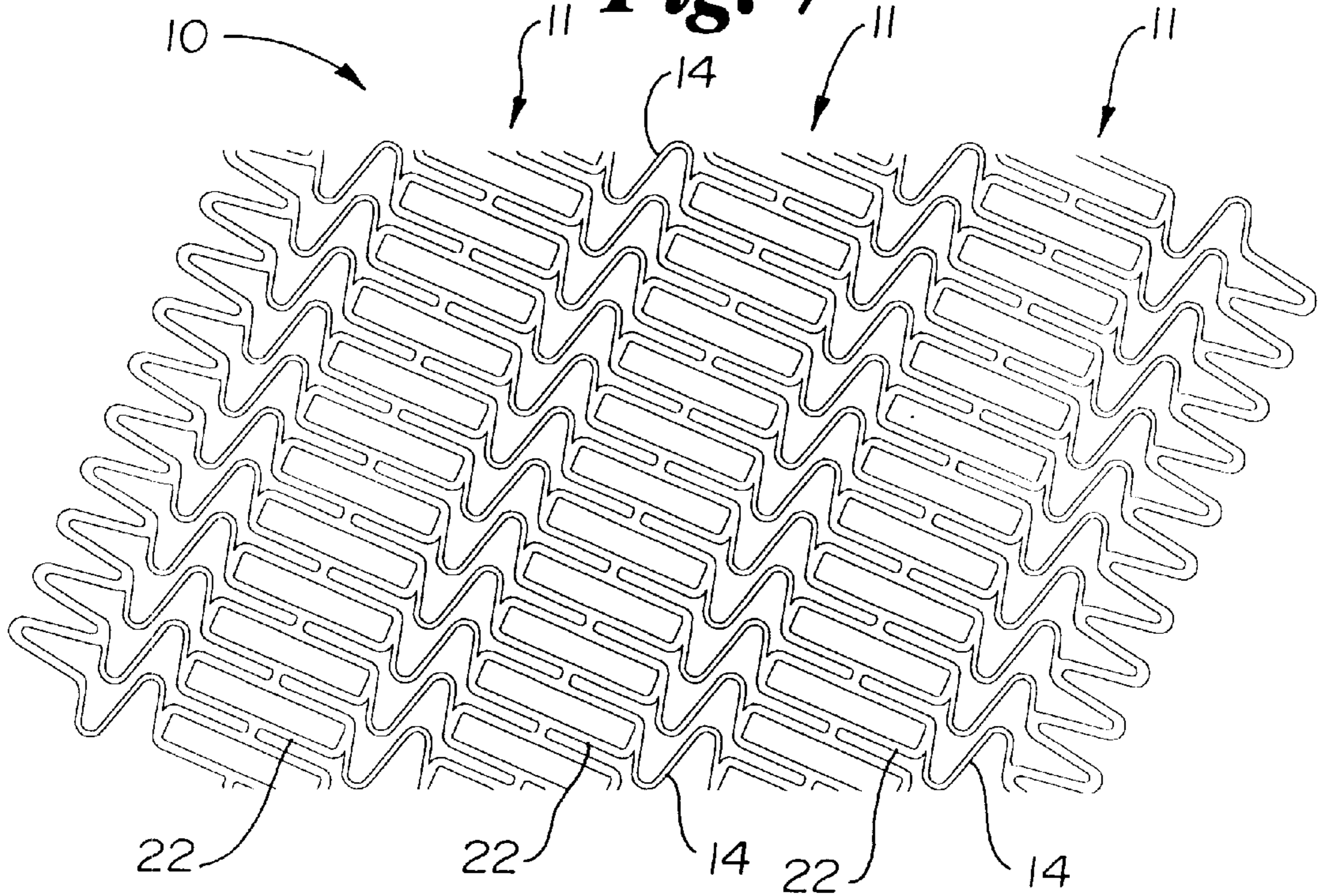




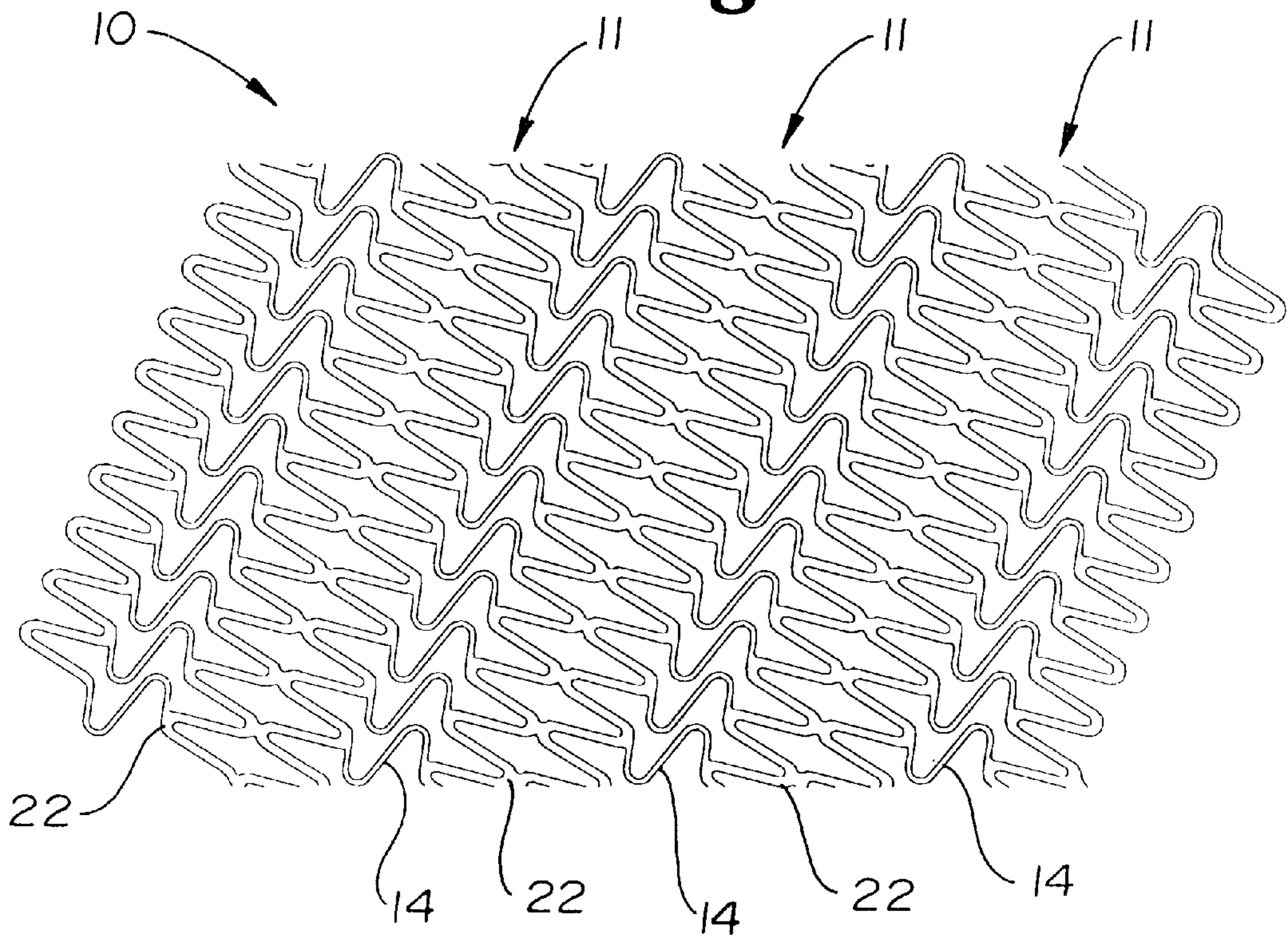
**Fig. 6**



**Fig. 7**

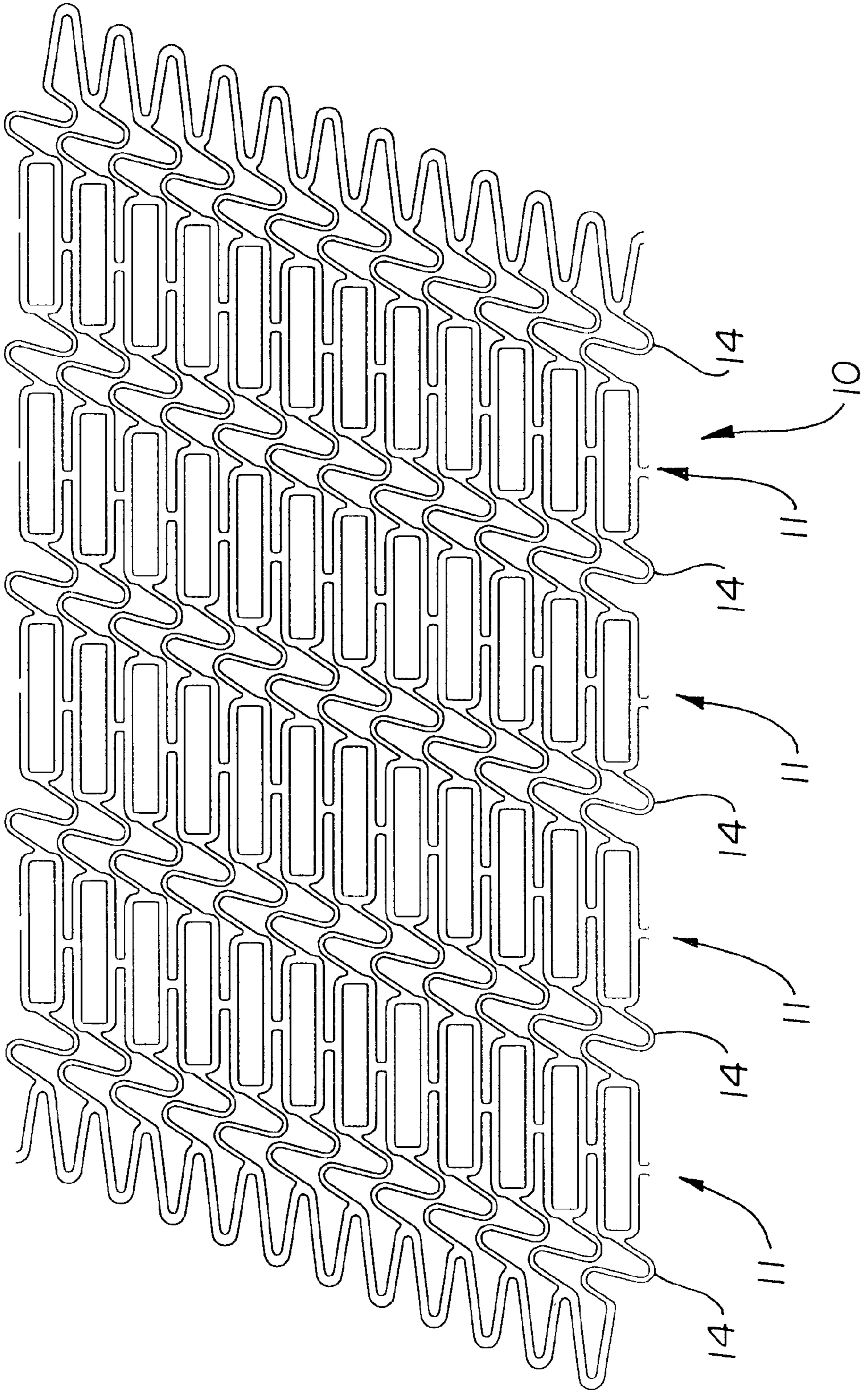


**Fig. 8**





**Fig. 9**



## HELICAL STENT DESIGN

### BACKGROUND OF THE INVENTION

The present invention relates to stents. A stent, generally speaking, is a device that can be placed within a body lumen or interior space for supporting and assuring patency of a lumen. Patency refers to the state of being freely open and is particularly important in the vascular system. The field of angioplasty is concerned with the reconstruction of blood vessels and stents are used, for example, for holding blood vessels open or for back tacking intimal flaps inside the vessels after angioplasty. More generally, however, stents can be used inside the lumina of any physiological conduit including arteries, veins, vessels, the biliary tree, the urinary tract, the elementary tract, the tracheal bronchial tree, the genitourinary system, and the cerebral aqueduct. Stents can be used inside lumina of animals and/or humans.

Stents are generally tubular in structure and are radially expandable between an unexpanded insertion size or circumference and an expanded implantation size or circumference which is greater than the unexpanded insertion size.

An important attribute of a stent is that it be radially compressible and expandable so that it will easily pass through a blood vessel or the like when collapsed and will expand or can be expanded to its implanted size after the implantation location has been reached. It is also desirable that a stent be generally flexible throughout its length so that it is easily maneuverable through bends and curves of the vascular system or the like to reach the implantation site and that the stent be conformable to the vascular site when expanded. It is also typically desirable that a stent have a substantial amount of open space so as to allow for endothelialization along its length to minimize foreign body response and to minimize interference with collateral blood vessels and the like.

There have been introduced various types of stents and various stent designs. Stents are generally categorized as being self-expandable, i.e., which expand by themselves and balloon expandable, i.e., expanded by a balloon inserted inside the stent.

From the view point of materials, stents can be categorized as being made from various metals such as stainless steel, nitinol and from various plastics.

Stents can be made from tubular stock structures from which a desired design may be cut or etched. Also they may be made from wire. Both of these types are well known.

Details of prior art stents can be found in U.S. Pat. No. 5,562,697, U.S. Pat. No. 5,540,713, U.S. Pat. No. 5,575,816, U.S. Pat. No. 5,569,295, U.S. Pat. No. 5,496,365, U.S. Pat. No. 5,344,426, U.S. Pat. No. 5,139,480, U.S. Pat. No. 5,135,536, U.S. Pat. No. 5,810,872, U.S. Pat. No. 5,226,913, U.S. Pat. No. 5,716,396, and U.S. Pat. No. 5,370,683.

This invention relates to all of the above-discussed types of stents and incorporates herein by reference all of the above patents specifically identified herein.

It is an object of the invention to provide, as a preferred embodiment, a stent comprised of a helically wound serpentine or undulating structure including curved connecting elements, i.e., curvilinear, which produces closed flexible cells in the expanded form. In combination the flexible cells yield a flexible, conformable stent which expands uniformly and provides good radial strength, scaffolding and fatigue characteristics when expanded.

Stents incorporating the design of the invention are preferably made from wire windings as in the prior art or from tubes such as metal tubes which are etched or laser cut to obtain the desired configuration of the stent in accordance with the invention.

The art referred to and/or described above is not intended to constitute an admission that any patent, publication or other information referred to herein is "prior art" with respect to this invention. In addition, this section should not be construed to mean that a search has been made or that no other pertinent information as defined in 37 C.F.R. §1.56(a) exists.

### BRIEF SUMMARY OF THE INVENTION

Generally speaking the present invention provides a stent comprised of two major structural elements, the first being a continuous elongated helical element preferably comprised of spaced undulating portions forming periodic end loop portions, i.e., a serpentine configuration, the helical element extending substantially over the length of the stent body to create a cylindrical stent configuration. The second element comprises a plurality of curvilinear, most preferably sinusoidal, connectors extending between and interconnecting at least some of the adjacent undulating portions, preferably connected to the end loop portions, of the helical element over its length. A double parallel helix or multiple parallel helices may also be used but the single helix as described hereinbelow is preferred.

### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side view of a stent extended in a flat form according to a first embodiment of the invention;

FIG. 1a is a front view of a stent before it is expanded;

FIG. 1b is a front view of a stent after it is expanded;

FIG. 2 is a view similar to FIG. 1 of another embodiment of the invention;

FIG. 3 is a similar view according to a third embodiment of the invention;

FIG. 4 is again a similar view of yet another embodiment of the invention;

FIG. 5 is a similar view of a further embodiment of the invention;

FIG. 6 is a similar view of still another embodiment of the invention;

FIG. 7 is a fragmentary flat form view of another stent embodiment;

FIG. 8 is a fragmentary flat form view of yet another stent embodiment, and

FIG. 9 is a fragmentary flat form view of another stent embodiment.

### DETAILED DESCRIPTION OF THE INVENTION

While this invention may be embodied in many different forms, there are described in detail herein specific preferred embodiments of the invention. This description is an exemplification of the principles of the invention and is not intended to limit the invention to the particular embodiments illustrated.

A stent 10 of a first embodiment the invention as shown in FIG. 1. The stent 10 is formed of a diagonally arranged helical band 11 which is arranged spirally in a cylindrical shape. The band 11 includes undulating portions 12 over its entire continuous length to provide a serpentine configura-

tion. As can be seen in the Figure, each of the undulating portions includes loop end portions **13**. Each loop end portion **13** is interconnected with an adjacent longitudinally spaced end portion **13** by a curvilinear connector element **14** which, in this embodiment, includes two bends or U-shaped portions **14a** and **14b** to form a connector having a preferred sinusoidal shape. Also as can be seen from FIG. **1** in this embodiment the interconnecting elements **14** preferably join end portions **13** at their extreme ends and extend directly between longitudinally spaced adjacent end portions. The connectors may be attached to other locations on the undulations other than the extreme ends. Also, with respect to the stent of FIG. **1**, it should be noted that the undulations are out of phase as indicated by lines **16**.

In this embodiment as in all of the embodiments disclosed, the stent is preferably formed from a tubular stock material by laser cutting. However, a tube may be etched as well. It is possible to form a desired configuration from flat sheet stock which is then bent into the desired cylindrical configuration. This is a procedure which is known in the art.

When a stent such as that shown in FIG. **1** is implanted in a body lumen, such as an artery, with the stent having an initial diameter  $D_1$  as shown in FIG. **1a** as delivered into the lumen to the desired location, the stent can be flexed and bent easily in a meandering lumen during delivery. Then, the stent is expanded to have a second diameter  $D_2$  as shown in FIG. **1b** which is larger than the initial diameter  $D_1$  whereby the stent is implanted.

When the stent is delivered and expanded, a delivery catheter assembly with an expandable member, such as a balloon, is preferably used as is known in the art. When the catheter assembly with a balloon is used to deliver the stent, the stent is mounted on the balloon and the catheter assembly is pushed into the implantation site. Then, the balloon is inflated, radially applying a force inside the stent and the stent is expanded to its expanded diameter.

Referring now to FIG. **2**, a second embodiment of the invention is shown which is similar in most respects to the embodiment shown in FIG. **1** with the exception that the sinusoidal connector elements **14** extend between end portions **13** which are not only longitudinally adjacent but are spaced upwardly or downwardly with respect to each other. Again, the serpentine configuration is out of phase.

Referring now to FIG. **3**, another embodiment of the invention is shown which is comprised of similar undulating structural elements **11** as is described with reference to FIGS. **1** and **2**. However, in this embodiment the connecting elements **14** are of a different configuration in the sense that the two U-shaped bends **14a** and **14b** are closer together, the resulting configuration not being strictly speaking "sinusoidal" but being curvilinear.

Other curvilinear configurations may also be used for the connector elements. For example, spiral configurations may be used such as those disclosed in U.S. patent application Ser. No. 08/846,164 filed Apr. 25, 1997, entitled "Improved Stent Configurations Including Spirals", which application is incorporated herein by reference in its entirety.

Referring now to the embodiment of FIG. **4**, it can be seen that this embodiment is also somewhat similar to that of FIG. **1**. However, in this embodiment the ends of the stent rather than being diagonal as shown in FIG. **1** are squared off with respect to the longitudinal axis of the stent **40**.

Referring now to FIG. **5**, another embodiment of a stent **50** according to this invention is shown. Again, the basic elements of this stent are similar to those of the preceding embodiments with the exception that the helical elements **11**

are not merely diagonal in arrangement but are curvilinear as well. This is demonstrated by reference to lines **18**.

Referring now to the embodiment shown in FIG. **6**, it can be seen that the undulations of the helical element **11** can be arranged so as to be in phase as is shown by lines **20**.

Referring now to FIGS. **7**, **8** and **9**, a fragment of a stent **10** is shown in each Figure including helical bands **11**. In FIGS. **7** and **9** the bands are made up of interconnected rectangular cells and in FIG. **8** the cells are joined serpentine or diamond shaped cells. In these Figures the curvilinear connector elements **14** are the preferred sinusoidal configuration.

The above Examples and disclosure are intended to be illustrative and not exhaustive. These examples and description will suggest many variations and alternatives to one of ordinary skill in this art. All these alternatives and variations are intended to be included within the scope of the attached claims. Those familiar with the art may recognize other equivalents to the specific embodiments described herein which equivalents are also intended to be encompassed by the claims attached hereto.

What is claimed is:

**1.** A stent for implantation in a body lumen, the stent having an open-ended tubular shape defined by a structure comprising:

at least one continuous elongated helical band element comprised of substantially uniform shaped and spaced undulating portions forming end loop portions, the helical element extending substantially over the length of the stent body, each of the undulating portions forming a peak and a trough, and

a plurality of curvilinear elements extending between and interconnecting the peaks of the adjacent, undulating portions of the helical element over its length.

**2.** The stent of claim **1** in which the undulating portions are in a sinusoidal pattern.

**3.** The stent of claim **1** in which the curvilinear elements extend between the loops of the undulating portions.

**4.** The stent of claim **1** in which the curvilinear elements include at least one bend.

**5.** The stent of claim **4** in which the bend is U-shaped.

**6.** The stent of claim **1** in which the curvilinear elements include at least two bends.

**7.** The stent of claim **6** in which the bends are U-shaped.

**8.** The stent of claim **6** in which the bends open in substantially opposite directions.

**9.** The stent of claim **1** wherein adjacent undulating portions of the helical element are in phase.

**10.** The stent of claim **1** wherein adjacent undulating portions of the helical element are out of phase.

**11.** The stent of claim **1** wherein the interconnecting elements extend between longitudinally spaced loop end portions.

**12.** The stent of claim **1** wherein the interconnecting elements extend between longitudinally spaced helical portions from and to loop end portions which are diagonally spaced from each other.

**13.** A stent for implantation in a body lumen, the stent having an open-ended tubular shape defined by a structure comprising:

at least one helically arranged band element forming a tubular configuration, the band being made up of a plurality of uniformly shaped closed, interconnected cells;

a plurality of curvilinear connector elements extending between and interconnecting longitudinally spaced portions of the band over its tubular length.

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14. The stent of claim 13 in which the cells of the band are rectangular.

15. The stent of claim 13 in which the curvilinear connectors are sinusoidal.

16. A stent comprising:

a continuous elongated helical band element comprised of undulating portions forming end loop portions, the helical band element extending substantially over the length of the stent body, each of the undulating portions forming a peak and a trough, each of the undulating portions disposed at an oblique angle relative to the longitudinal axis, and

a plurality of curvilinear elements, each of the curvilinear elements disposed at an oblique angle relative to the longitudinal axis, the curvilinear elements forming a helical pattern between and interconnecting the peaks and troughs of the adjacent, undulating portions of the helical element over its length.

17. The stent of claim 16 wherein the undulating portions have a substantially uniform size and shape.

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18. The stent of claim 17 wherein all of the undulating portions are disposed at substantially the same angle relating to the longitudinal axis throughout the helical band.

19. The stent of claim 17 wherein one or more of the undulating portions are disposed at different oblique angles, relative to one another, relating to the longitudinal axis throughout the helical band.

20. The stent of claim 17 wherein all of the curvilinear elements are disposed at substantially the same angle relating to the longitudinal axis throughout the helical band.

21. The stent of claim 17 wherein one or more of the curvilinear elements are disposed at different oblique angles, relative to one another, relating to the longitudinal axis throughout the helical band.

22. The stent of claim 13 further comprising at least one slot which is at least partially interspaced between the interconnected closed cells.

23. The stent of claim 13 wherein the cells are substantially diamond shaped.

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